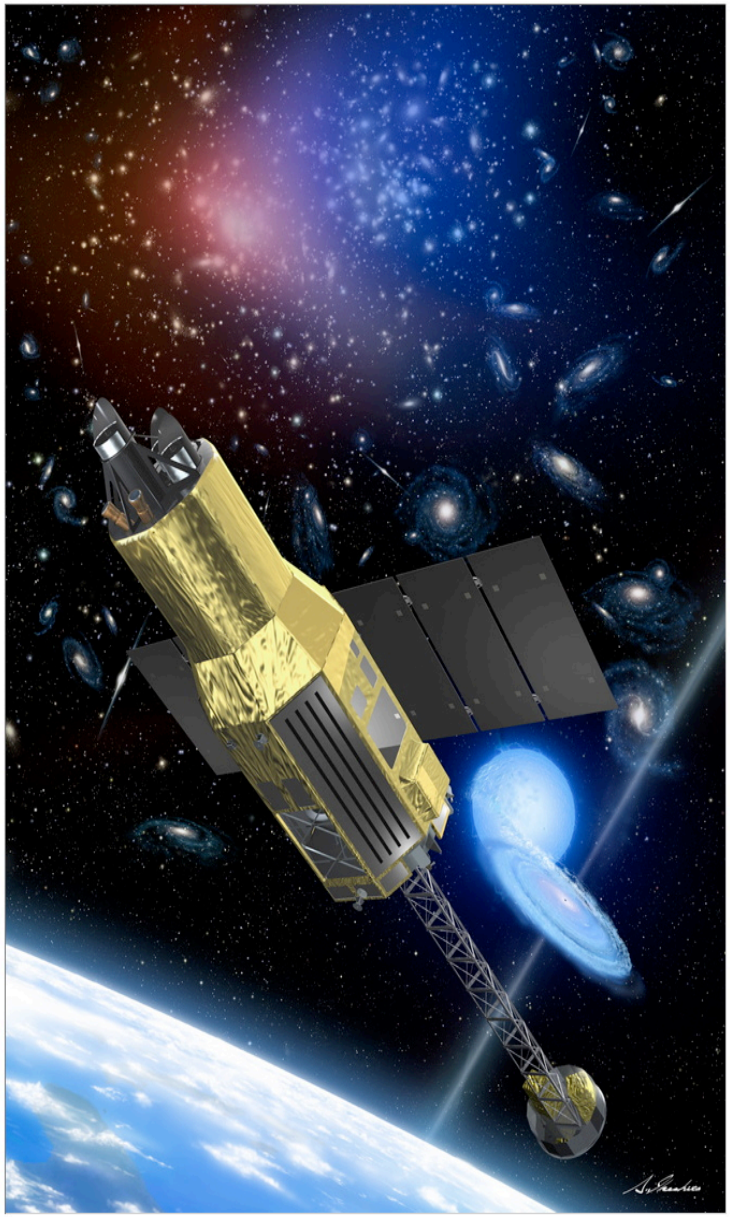


NASA Lessons Learned

Astro-H Mission

Soft X-Ray Spectrometer Instrument

SMEX Mission of Opportunity

Category 3 Enhanced Class D
NASA Contribution: Enhanced Class C and Cost-capped

International Partner: JAXA

SXS Instrument co-developed by
NASA/GSFC & ISAS/JAXA

Launched: 17 February 2016 (now called Hitomi)

March 24, 2016

Astro-H SXS Instrument

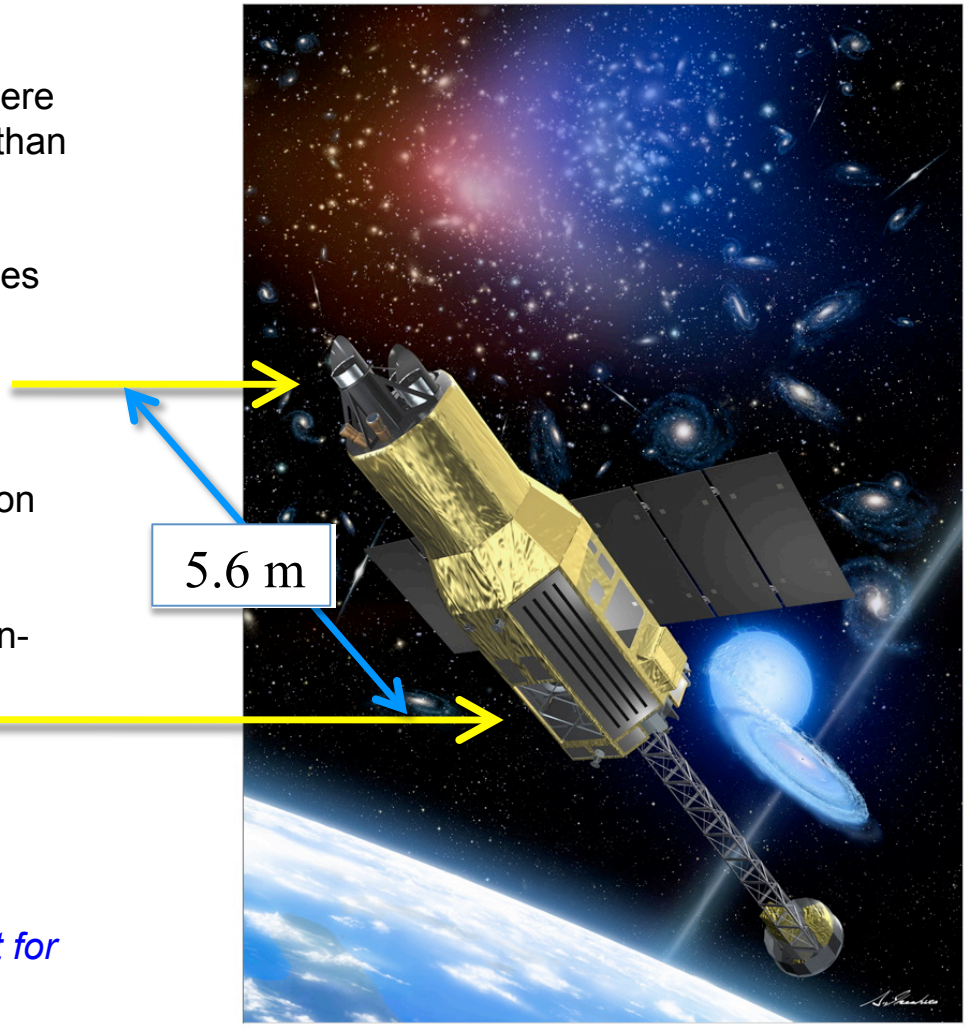
The SXS provides the high-resolution spectroscopy capability to cover the range where all astrophysical abundant elements (heavier than He) emit characteristic x-rays.

High throughput, low mass x-ray mirror provides large effective area

SXS based on x-ray calorimeter array

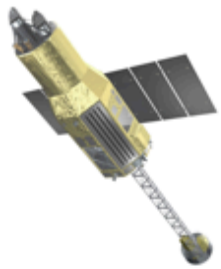
- Spectrometer with high spectral resolution and high quantum efficiency.
- Thermal detection of x-rays provides non-dispersive spectroscopy.
- This enables observations of extended sources without compromise to spectral resolution.

It is the most sensitive spectrometer ever built for energies above ~ 1 keV.



Astro-H Soft X-ray Spectrometer (SXS) Instrument Block Diagram

NASA Contribution



Pre-Collimator & Thermal Shield
Mirror Assembly

Soft X-ray Telescope

to HCE

Filter Wheel &
Modulated X-ray Sources

Contamination Baffle

Reflector Room

Gate Valve

Helium
Tank

Heat
Pipes

NEA
Valves
(x4)

Filter Wheel Electronics

FWE

Amplification
& Digitization

Xbox

Pulse Shape
Processor

PSP

ADRC

ADR
Controller

Power Supply
Unit

PSU

Science
Data

DIST

SWR (A/B)

JT circuit
Driver

JTD

Pre-Cooler
Driver

PCD

Shield Cooler
Driver

SCD

SXS Instrument

HCE

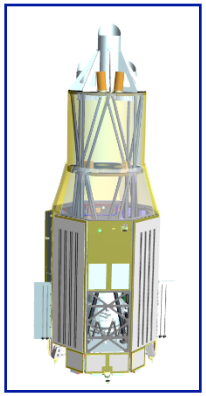
MSE

NEAC

PCU

SMU

SXS Instrument Integration/Test
NASA/GSFC Hardware



Spacecraft

Launch

Spacecraft Assembly, Integration and Testing

Dewar

Dewar Assembly, Integration and Testing

Japan

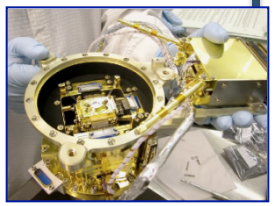
USA

CSI & harnesses

Electronics & harnesses

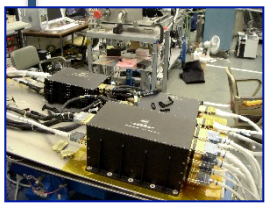
Test Dewar, Vibration Dewar

Calorimeter Spectrometer Insert



Detector Assembly

ADR



Electronics & Harnesses

Aperture Assembly

Filters

SXT

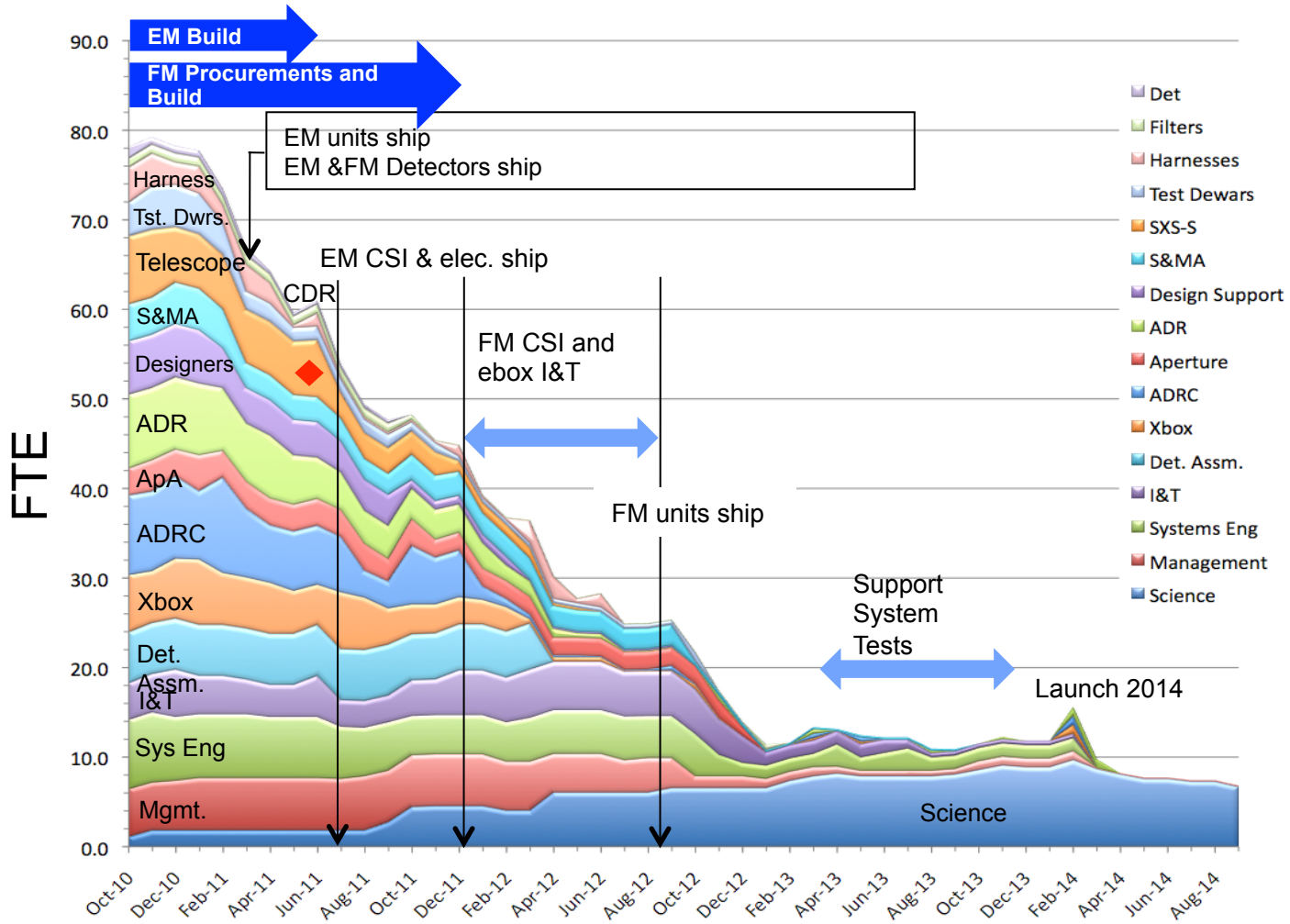
Starting On The Wrong Foot

- Re-plans approved in two DPMCs that increased the budget
  - June 2010 (KDP-C): from $47 M to $53 M
  - February 2011: from $53 M to $60 M
- Higher than planned spending for a $60 M instrument
  - Unsustainable average monthly burn rate of ~$1.74 M in FY11
  - 60% of funding spent by April 2011
  - Estimated ~$2 M overrun by fiscal year 2011 end if no action taken
- Budget plan not credible, and was developed prior to detailed schedule
  - Assumed 'head start' on Astro-H due to work from Astro-E and Astro-E2
    - Underestimated complexity in design, build, manufacturing, processes and testing
    - Instrument cost proposed did not include a Phase A
    - Underestimated development effort – assumed similarity in hardware design
    - Same key personnel were not available for Astro-H
    - Assumed build and test facilities ready to go from Astro-E and Astro-E2
  - Planned aggressive staff ramp-down begins *before* CDR

Starting On The Wrong Foot (cont'd)

- Schedule plan was not executable
  - Did not account for interleaved effort between NASA and JAXA for EM work
    - Frequent travel to and from Japan by key personnel at critical junctures of NASA hardware activities
  - Overlapping FM development schedule with JAXA EM test schedule
    - Both activities required same key personnel to accomplish the work, but in 2 different countries
  - No EM hardware had as yet been delivered to JAXA
    - EM hardware was still in design; some at breadboard level
- NASA team
  - Conflicts between PI and IM over final decision authority
  - Inexperienced instrument management team (IM, RA and Scheduler)
  - Inexperienced key personnel – some from Astro-E/E2 did not return to work Astro-H

Staff Ramps Down *Before* CDR



Best Practices & Lessons Learned

1. For PI-led missions: formally define lines of authority and span of control between PI and IM/PM
2. Objective assessment of programmatic complexity
   - Number of organizational interfaces
   - Geographical location of critical path activities (integration, testing)
   - For international partnerships: understand cultural differences that impact hardware approach for build and test
3. Must consider more than heritage (TRL assessment) – must also assess complexities for:
   - Build, assembly, manufacturing, coatings, bonding, GSE
   - System-level aspects (interfaces, integration, testing)
4. Contingency/reserve posture (schedule and cost) must be risk-based!!
   - Complexity (#3 above), uncertainties (driving requirements), availability of resources for top 2 critical paths
5. Build-to-print means *absolutely no changes in anything* from before
   - Design, materials, assembly, manufacturing, processes, procedures, coatings, drawings, schedule, budget, etc. – everything is the same!!

Best Practices & Lessons Learned

6. Staffing skill sets and experience must be appropriate for the type of work
   - Know-how has to be on the team – organizational knowledge and experience are not sufficient
7. Aggressive schedule and budget plans are a sure recipe for overruns on science instruments
   - NRE (Nonrecurring Engineering) phase is *always* difficult to estimate schedule and cost without a crystal ball
   - Shortening durations to make it fit is like pouring 8 oz. water into 4-oz cup
8. Want fast-paced while staying on plan?
   - Driving requirements, interfaces and parameters must be well understood before starting the design
   - Take advantage of proven technologies already flown…not about to be flown
   - Simplify build, manufacturing, integration and testing approach
   - Resources must match the plan and be available at start of key activities
9. Off the plan by greater than 10%..?
   - Act now rather than later; use risk-based decisions to de-scope and/or eliminate activities in the plan